DEPARTMENT OF AGRICULTURE,
CEYLON.

BULLETIN No. 43.

SHOT-HOLE BORER.

(*XYLEBORUS FORNICATUS*, Eich.)

TREATMENT OF PRUNINGS ON INFECTED ESTATES.

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Peradeniya,
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DEPARTMENT OF AGRICULTURE, CEYLON.

BULLETIN No. 43.

SHOT-HOLE BORER.

(*Xyleborus fornicatus*, Eich.)

Treatment of Prunings on Infected Estates.

THE question of the treatment of tea prunings on estates infected with Shot-hole Borer Beetle dates back to the year 1901. Owing to the number of factors—agricultural, economic, and entomological—which have to be considered in determining the most profitable disposal of the large amount of material to be dealt with, a good practical decision has not hitherto been easy to arrive at.

Entomological Factors.

Dealing first with the *entomological* side of the question, four different methods of disposal of prunings have been in general practice on estates to a greater or less extent :—

(1) Leaving the prunings on the ground.
(2) Burying the prunings to depths varying from 4 to 18 inches below the ground level.
(3) Burning the prunings.
(4) Burying the leaves and smaller wood, and burning the heavier wood.

In each case it has been essential to find out what is the effect of the four methods adopted upon the breeding habits and multiplication of the beetle during wet and dry seasons.

I.—Prunings left on the Ground.

The Shot-hole Borer Beetle belongs to a genus of insects which usually breed in dead and dying wood, and authorities not actually acquainted with the beetle have pointed out that, were the prunings left on the ground for a short time, beetles from healthy trees would congregate in the prunings in such numbers as would make the burning of prunings after a short period likely to exercise a complete control of the insect. Unfortunately the insect is not attracted in any way to cut branches, even in the heavy monsoon rains. The prunings left on the ground do not act as a trap for the beetles, which are exceptions to most of their congeners in habit.

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The next point to consider is, to what extent the young stages from the egg to the pupa can develop in order to emerge as adult beetles from the galleries, in both wet and dry weather. Mr. E. E. Green and the late Mr. Rutherford have both supplied observations, which have been added to more recently :—

In Wet Weather.

Ulapane : On 3rd day after pruning, all stages alive. October, 1903.

Yatiyantota : On 3rd day after pruning, all stages alive. April, 1913.

Peradeniya : On 13th day after pruning, a few adult beetles alive. December, 1913.

Kandy : On 8th day after pruning, only adult beetles alive. April, 1915.

Peradeniya : On 21st day after pruning, a few young adult beetles alive. November, 1916.

In Dry Weather.

Ulapane : On 3rd day after pruning, all stages alive ; on 4th day after pruning, only adult stages alive ; on 7th day after pruning, only adult stages alive ; on 10th day after pruning, all beetles emerged. July, 1909.

Peradeniya : On 2nd day after pruning, only adult stages alive ; on 7th day after pruning, all beetles emerged. March, 1915.

From numbers of similar observations it is established that beetles can continue to emerge in wet weather for 21 days, in dry weather for only 10 days, at the outside.

An experiment carried out at Balangoda in June, 1916, is worthy of mention. Branches on growing bushes near the time of pruning were bent down, and the galleries of Shot-hole Borer in them fractured, so that the top half of the gallery in each case dried quickly, and the lower half was left practically under normal conditions. Though some of the branches were still green, but faded, above the point of fracture, few larvæ were alive in galleries examined on the 11th day, and on the 16th day only adult beetles were alive.

Below the point of fracture, however, larvæ were still alive and numerous on the 16th day. It transpires, then, that the larvæ require a considerable amount of moisture for their development, and it is certain that *eggs*, laid after the prunings are cut, cannot develop to the adult stages under any climatic conditions.

In wet weather pupæ and well-advanced larvæ can become adults, but in dry weather only pupæ 4 days previous to reaching maturity can emerge later as adults.

If pruning is carried out in the rain, therefore, more adult beetles will emerge from the cut prunings left on the ground than if pruning is done in the dry season.

The pupal stage being a short one, the number of beetles maturing in the dry season is small, but all beetles already matured will continue to emerge for a period of 10 days after the prunings are cut, though most will have escaped by the 4th day. If the prunings are left on the ground till the leaves fall off and the wood is then destroyed by fire, the beetles have time to make good their escape.

II.—Buried Prunings.

(*a*) *Development below the Ground.*

The late Mr. Rutherford made the first experiments upon the habits of the Shot-hole Borer under ground. In September, 1913, he buried tea stems containing galleries in glass jars 5½ inches and 7½ inches under earth; on the 31st day after burial he found all stages of the insect alive in the galleries. From July to October, 1914, he kept infected branches in a closed tin box. After 24 days all stages of the insect were still alive, after 62 all stages except the egg and after 89 days adult beetles (some young) were still alive.

From June to July, 1914, he examined, daily, prunings buried on an estate at Ulapane. On the 29th day after burial all stages were still present in the galleries, 7·69 inches of rain having fallen during the period of examination. Another observation made in May, 1914, showed that most of the beetles had emerged from the galleries by the 32nd day, but larvæ were still found at the time, after a rainfall of 13·20 inches.

Further records are as follows :—

Balangoda: On 18th day after burial, all stages alive. March, 1915.

Kandy: On 19th day after burial, all stages alive. June, 1916.

Peradeniya: On 31st day after burial, all stages alive. February, 1918.

Peradeniya: On 56th day after burial, female beetles alive with eggs, but no other stages present. February, 1918.

Peradeniya: On 63rd day after burial, a few adult beetles still alive. February, 1918.

The latter records were taken in dry weather, the last being a period of extreme drought, the depth to which the prunings were buried varying from 4 inches below the surface to as much as 18 inches.

It is obvious that Shot-hole Borer not only live, but can actually breed and multiply in prunings buried to any depth consistent with estate conditions and in any climatic condition prevailing. Heavy rains tend to shorten the breeding period under ground, but not to any very considerable extent.

It may be concluded with certainty that as long as the buried prunings are in a fit condition for the insect to breed in, which is for a period of not less than one month, that normal development takes place, even new galleries being constructed by emerging beetles and eggs laid in them, though the latter do not survive in the second generation.

(b) *Emergence of Beetles through the Soil.*

[*Note.*—In the following experiments, the figures given for the emergence of beetles applies in all cases to the female.]

Mr. Rutherford, in September, 1913, placed living beetles at the bottom of a darkened glass tube 2 inches in diameter and covered them with earth to a depth of 9 inches; living beetles were found on the surface on the 2nd and 7th and 9th day after burial.

Tea stems containing galleries were buried similarly, with these results :—

Table I.—Peradeniya, September, 1913.

Emergence of Beetles through Soil.

Depth buried. Inches.	Days after Burial.	Female Beetles on Surface.
5	12	1
$5\frac{1}{2}$	1	1
	23	2
	26	1
	28	1
	31	1
	Total	6
$6\frac{1}{2}$	19	1
7	12	1
$7\frac{1}{2}$	1	1
	18	1
	22	2
	24	1
	28	1
	31	1
	Total	7

The experiments show that adult beetles can make their way through soil of considerable depth and emerge naturally from their galleries, but they do not represent the conditions which prevail on estates.

Accordingly, some further results were obtained from prunings buried in a tea field in wire cages with a glass vessel on the top, to which beetles could find their way and so be collected. (See Fig. 1.)

Table II.—Peradeniya, August 7 to September 6, 1917.

On Level Ground.

Depth buried.	Number of Branches.	Days after Burial.	Rainfall to Date.	Female Beetles emerged.
Inches.			Inches.	
6–9	25	—	9·77	—
9–12	25	8	3·40	1
12–18	25	8	3·40	5
		25	6·89	3
		28	7·77	1
			Total	9

Peradeniya, November 15 to December 20, 1917.

On Sloping Ground.

Depth buried.	Number of Branches.	Days after Burial.	Rainfall to Date.	Female Beetles emerged.
Inches.			Inches.	
6–9	12	8	5·61	1
6–9	16	—	15·06	—

During heavy rain and at a depth of 12 to 18 inches beetles emerged, but it is curious to note the small number emerging in cases where the branches were buried to a smaller depth. It is very probable that the beetles found their way out under the sides of the cages. In the first experiments the prunings were dug up on the 82nd and 92nd days respectively, and no living insects were found in the galleries.

In the last two experiments the prunings were dug up on the 21st day, and were found to contain living insects in all stages. They were replaced and again dug up on the 33rd day, when only few galleries were found to be tenanted, but they contained living larvæ, pupæ, and adults. On the 35th day a number of young adult beetles were still present, but larvæ and pupæ had disappeared. With a view to obtaining more satisfactory results, an experiment was carried out on a much larger scale, the prunings being buried in ordinary estate holes and covered with inverted tea chests (with the top removed),

holes being bored in the sides of them and glass tubes fixed on with wax, the female beetles being readily attracted by light in these circumstances. (See Fig. II.)

Sixteen lots of prunings, 12 in each hole, were buried to a depth of 3 to 7 inches.

Table III.—Peradeniya, February 20 to April 16, 1918.

Days after Burial	Rain-fall. Inches.	Emergence of Beetles into Tubes. On Slope. I.	II.	III.	IV.	V.	VI.	VII.	VIII.	On Level. IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
1	..	—	..	1.	—	—	—	—	1.	—	—	—	—	—	—	—	—
2	..	—	—	—	—	3.	—	1.	—	—	—	1.	—	—	—	1.	3.
3	..	—	—	—	—	—	—	—	—	—	—	1.	—	—	—	—	—
4	..	—	—	—	2.	—	2.	—	—	—	—	—	—	—	—	—	1
5	..	—	—	2.	—	—	—	1.	—	1.	—	3.	—	—	—	1.	1
6	..	—	2.	—	—	—	—	—	—	3.	—	—	—	—	—	—	—
7	..	—	—	1.	—	—	—	—	—	—	—	2.	—	—	—	—	—
8	..	—	—	—	—	—	—	—	1.	—	—	—	—	—	—	—	—
9	..	—	—	1.	—	—	—	—	—	—	—	—	—	—	—	—	—
10	..	—	2.	—	—	—	—	—	—	—	—	1.	—	—	—	—	—
11	..	—	1.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	..	—	—	—	—	—	—	—	1.	—	—	—	—	—	—	—	—
13	..	—	—	—	—	—	1.	—	—	—	—	1.	—	—	—	1.	—
14	..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.	2
15	..	·04	1.	—	—	—	—	—	—	—	1.	—	—	—	—	—	—
16	..	—	—	—	—	—	—	—	—	1.	—	—	—	—	—	—	—
21	..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.	—
23	..	—	—	—	—	1.	—	—	—	—	—	—	1.	—	—	—	—
24	..	—	—	—	1.	—	—	—	—	—	—	—	—	—	—	—	—
29	..	—	1.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33	..	·28	—	1.	—	—	—	—	—	—	—	—	—	—	—	—	—
34	..	—	—	—	—	—	—	—	—	1.	—	—	—	—	—	—	—
41	..	·96	—	—	—	1.	—	1.	—	—	—	—	—	—	—	—	—
47	..	1·61	—	1.	—	—	—	1.	1.	—	—	—	—	—	—	—	—
54	..	3·94	1.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	..	3·94	9	8	—	6	2	4	2	7	1	9	2	—	1	1	7	3
					Total	..	38								24			

It is seen at once that considerable variation exists in the number of beetles emerging in each case. During a drought, such as that experienced, there could be no difference of condition in the lots buried on the level from those buried on sloping ground, so that variation in numbers emerging depends on the condition of the galleries when buried, and possibly on escape of beetles under the sides of the cages below the ground. For instance, the prunings of lots XV. and XVI. were examined on the 32nd day, and the galleries then contained very large numbers of healthy insects in all stages, though only three beetles had emerged from lot XVI. On the 58th day lot XII. was examined and no signs of living insects were found, the condition of the galleries indicating that very few living insects were present when the prunings had been buried. In lot XIII., on the other hand, examined on the same day, a female beetle was found with an egg just laid. From various observations made during other experiments, it seems that the female beetle is able to find its way with considerable ease beneath the ground.

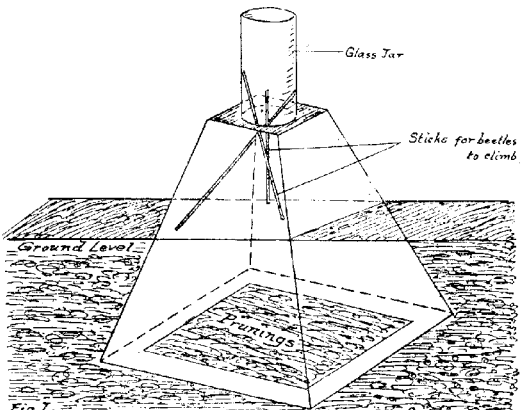

Fig I.
Wire Cage used in Burying-Pruning Experiments.

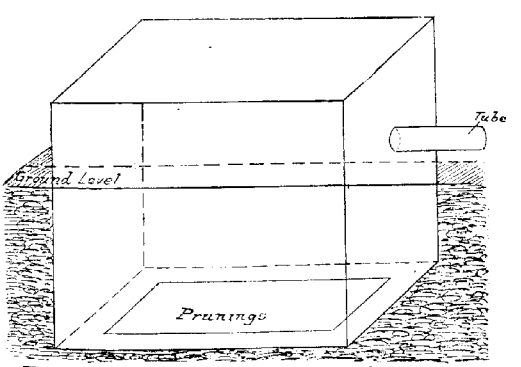

Fig II
Inverted wood chest with glass-tube for emergence of beetles

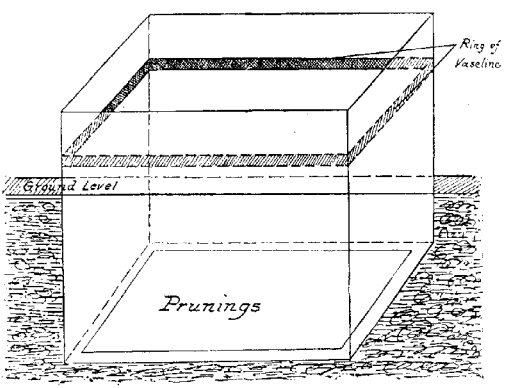

Fig III.

Wood-chest without lid, and with Vaseline ring to prevent escape of beetles.

A final experiment was made with a view to making observation under the most natural conditions possible. Four lots of infected prunings weighing 6 lb. each (the approximate weight of prunings buried in a single hole under estate conditions) were buried in holes 9 inches deep ; a tea chest was sunk into each hole, but here both top and bottom of the chest were removed, so that the ground above the prunings was open to the atmosphere. A ring of vaseline was smeared round the inside of each chest about 4 inches above the ground level, to stop beetles climbing the sides during their escape from the chests. (See Fig. III.)

Table IV.—Peradeniya, May 28 to July 4, 1918.

Days after Burial.	Rainfall to Date from May 1, 13·23 Inches. Inches.	Emergence of Female Beetles. I.	II.	III.	IV.
2 ..	— ..	1 ..	— ..	— ..	—
4 ..	— ..	— ..	— ..	1 ..	—
13 ..	— ..	— ..	— ..	1 ..	—
37 ..	10·94 ..	— ..	1 ..	— ..	—
Total ..	10·94	1	1	2	—

On the 22nd day there was about a quarter of an inch of water covering the ground in the cages. After this had subsided a beetle still was able to emerge.

Naturally a large number of emerging beetles would escape detection and fly away under the circumstances, but the experiments show clearly that beetles can and do emerge during drought, and also after the heaviest rain.

(c) *Effects of Manures and Chemical Salts buried with Prunings.*

(1) *Slaked Lime.*—In October, 1913, Mr. Rutherford covered tea stems containing borer with earth mixed with half ounce of slaked lime to a depth of 6½ inches and 5 inches in glass jars. On the 19th day after burial one beetle was found on the surface of the earth in the 6½-inch jar, and all stages of the insect were then found living and healthy in the stems, with the exception of eggs, which were absent.

In the experiment Table III. (see page 6) lots Nos. III. and XI. were each buried with half pound of slaked lime, representing 400 lb. to the acre. From No. III. no beetles emerged, but from No. XI. two beetles emerged.

The prunings of No. XI. were dug up 54 days after burial; no living and no dead insects were found, and it is likely that the prunings in these two lots contained very few galleries at the start.

From experiments with quicklime, which rapidly becomes slaked in the soil, it is certain that ordinary slaked lime has no effect upon the successful development of the beetles underground.

(2) *Quicklime.*—Mr. Rutherford, in November, 1913, found that the development was similarly unaffected in stems buried to 7 inches and 5½ inches in glass jars with earth containing quicklime. Lots Nos. I. and IX. (see Table III.) were buried with half a pound of fresh quicklime each (= 400 lb. per acre); from them respectively 9 and 1 beetles emerged. It is evident, then, that the heat generated by a considerable quantity of quicklime is not sufficient to destroy the insects, or interfere with their emergence. On the 61st day after burial living adults were found in the galleries.

(3) *Nitrolim.*—In the experiment described in Table IV. lot No. III. was buried with half pound nitrolim (= 200 lb. per acre). Two beetles emerged from these prunings, and 107 days after burial the nitrolim was still in the hole with the prunings.

(4) *Calcium phosphate.*—2 oz. (= 100 lb. per acre) were placed with lots Nos. V. and XIII. respectively in the experiment shown in Table III. Three beetles emerged from them on the 23rd and 41st day after burial. Dug up on the 57th day after burial a living female, which had deposited an egg, was found in one gallery.

(5) *Ammonium sulphate.*—2 oz. (= 100 lb. per acre) were placed with lots Nos. VII. and XV. respectively in the experiment Table III. Nine beetles emerged from these during 47 days, and lot No. XV. was dug up on the 31st day after burial; the galleries contained some large broods of young adult beetles, both male and female, and some also contained eggs, in addition to larvæ.

(6) *Occlusion of Galleries.*—It was observed during the above and previous experiments that a number of entrances leading to galleries made by the beetles were found to be healed over by a wad of cambial tissue, or "callus," when the prunings were dug up. At first it was naturally supposed that this had taken place before the prunings were buried, but living insects were found in these occluded galleries 21 days after burial. Sixteen branches had been buried to a depth of 4 to 9 inches on the occasion, and about 15 inches of rain fell during

the period. On the 35th day the branches were examined, with the following result :—

Number of open galleries	10	.. All empty.
Number occluded by earth	17	.. 14 empty; 2 containing 5 females and 2 male insects alive, 1 containing 1 dead female.
Number occluded by callus	12	.. 11 empty; 1 containing 2 females, 1 young and 1 mature, both dead.
Total	.. 39	

Thus, more than one-fourth of the galleries were found to be occluded by callus: though undoubtedly some of them had been closed before burial, the odour of decay emanating from some of them when opened suggested, but did not prove, that insects had died in them after burial.

It is evident that simple occlusion by earth does not affect the inmates to any great extent. This line of investigation was followed up by taking note of the general amount of occlusion of galleries in prunings buried with the various chemical salts and manures.

After 56 days, with a long period of drought, most occluded galleries were found in prunings buried with calcium phosphate, with slaked lime fewer, and practically none with unslaked lime and ammonium sulphate.

Doubtless rain increased the capacity of the branches for healing, and final observations were made on 6 branches containing 20 galleries in all, buried to a depth of 6 inches, and covered with a very considerable quantity of powdered calcium phosphate on May 9, 1918, at Peradeniya. Four of these galleries were occluded before burial and 16 were open, and many contained living insects; but on the 6th day after burial it was found that 4 galleries had begun to heal, leaving only 12 open. It is fairly obvious that this occlusion by callus takes place in newly made entrances, when the cambial tissues have not been affected to any extent by physiological conditions set up in the galleries, involving the possible death of only a few female beetles at most, while the majority of the larvæ, pupæ, and young adults are free to emerge.

Conclusions.—It may be safely concluded that the more soluble fertilizers and lime (slaked and unslaked) do not hinder the emergence of beetles from buried prunings, and the most remarkable occlusion of galleries in branches cut from the tea bush is not promoted sufficiently, nor does it exist in ordinarily buried prunings to a sufficient extent, to render the practice of burying prunings wholesale a means of control in combating the pest.

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(b) Artificial Fumigation.

It was thought possible that the generation of poisonous gases by substances placed in holes with prunings might result in the death of insects by transfusion of these gases into the galleries. Accordingly it was resolved to generate hydrogen cyanide slowly from (1) a mixture of potassium cyanide (KCN) and sodium bisulphite ($NaHSO_3$), and (2) ordinary potassium cyanide. In addition, nitrolim gives off small quantities of gases, which, it was thought, might have a toxic action on the insects.

The experiments were carried out at Diyaluma, Koslanda, in April, 1915, 4 branches being buried to a depth of 9 inches in each case.

(1) (*a*) Sodium bisulphite 1⅝ oz., potassium cyanide 1½ oz. Date buried 17/4/15. Date examined 19/4/15. Period 2 days. The branches contained 8 galleries.

Galleries containing eggs and no adult beetles ..	2
Galleries containing dead larvæ and pupæ, but no adult beetles	2
Galleries containing dead larvæ and pupæ and adults	1
Galleries containing living larvæ and pupæ, but no adult beetles	1
Empty	2

(*b*) Sodium bisulphite 4 oz., potassium cyanide 2 oz. Date buried 19/4/15. Date examined 3/5/15. Period 14 days. The branches contained 20 galleries.

Galleries containing dead larvæ and beetles ..	3
Galleries containing living larvæ and beetles ..	1
Galleries containing one dead adult female (old galleries)	2
Galleries containing one dead adult female and eggs (fresh galleries)	2
Galleries containing eggs, but no adult beetles ..	1
Empty galleries (old)	6
Occluded galleries	4
Empty galleries (fresh)	1

(2) Potassium cyanide 2 oz. Date buried 17/4/15. Date examined 3/5/15. Period 14 days. The branches contained 11 galleries.

Galleries containing dead larvæ and no adult beetles (occluded)	1
Galleries containing living eggs, larvæ, and beetles ..	1
Empty galleries (many occluded) ..	9

(3) Nitrolim 2½ oz. Date buried 17/4/15. Date examined 19/4/15. Period 2 days. The branches contained 4 galleries.

Galleries containing living larvæ and adult beetles ..	1
Galleries containing living adult beetles ..	1
Empty galleries (old)	2

(4) Controls. Sodium bisulphite 4 oz. Date buried 19/4/15. Date examined 3/5/15. Period 14 days. The branches contained 13 galleries.

Galleries containing living eggs, larvæ, and adult beetles	6
Empty galleries (old)	7

(5) Without mixture. Date buried 17/4/15. Date examined 19/4/15. Period 2 days. Many galleries containing insects alive in all stages. A considerable number old and vacated.

Conclusions.—On account of the danger of using cyanide of potassium on estates even in the smallest quantities, and especially in the soil, these experiments were not continued.

It is seen from them that the gas generated by sodium bisulphite and potassium cyanide is very effective in, at any rate, killing the majority of insects, as is probably also potassium cyanide alone. Of interest also is the fact that the female beetle is in many cases forced to abandon the gallery and the brood. In addition, the cost of these salts would be prohibitive on the estate scale. Nitrolim does not affect the brood or beetles in any way. This is also seen from the experiment in section (c) (page 8).

III.—Burning Prunings.

The practice of burning prunings has been religiously carried out for many years on more than one estate in Ceylon. Of the fact that this method holds a certain control on the pest there can be little doubt. As early as February, 1901, Mr. Green writes in a note: "I am surprised to find that the prunings could be burned quite green. The Superintendent had them consumed within an hour from the pruning. I found by experiment that a very small exposure to the heat suffices to kill the contained insects. The branches need not actually be even scorched. The wood and sap become hot enough to kill the insects before the fire has actually reached them."

It has been mooted that the beetles escape from the prunings while they are being heaped for burning, but this is not the case; contained insects move to the innermost recesses of their galleries when they are disturbed by the cutting of branches and the heat of the flames.

When rain is continuous it is not possible, in many cases, to burn the prunings immediately, but it has been found that the young adult insects do not emerge readily in the wet seasons, and the prunings can therefore be left on the ground with safety until the rain stops, an hour in the sun proving sufficient to make the branches combustible.

As a practice, however, the wholesale burning of prunings is not to be recommended, for reasons given in the next section. It has on many occasions been necessary to advocate the burning of prunings on estates, as this has hitherto been the only means possible of actually killing the insects in any numbers, and the recommendation had to be made for want of a better practice.

IV.—Burying the Leaves and Smaller Wood, and burning the Heavier Wood.

This practice may be called the "fractional" destruction of prunings, and is carried out on some estates, in order to get rid of the excessive wood which lies about in the tea fields, and later effects much damage in blocking drains. An experiment was carried out on an estate in Passara (Uva) to determine how many insects would escape destruction, the slashing off of the leaves being carried out by coolies immediately after pruning, without interference. Twenty-eight bushes were thus pruned, and the following figures obtained :—

		Per Acre of 3,200 Bushes.
Number of tenanted galleries in wood to be burnt	894 =	102,170
Number of tenanted galleries in small wood to be buried ..	35 =	4,000
Number of untenanted galleries in small wood to be buried ..	52 =	5,940

Thus, the proportion of galleries in the wood to be burnt is, roughly, 90 per cent., and that of the tenanted galleries which escape destruction is only 4 per cent., under ordinary estate conditions. If the leaves and small twigs are slashed off before pruning, it is probable that all the galleries in the prunings could be destroyed; but the latter method is found to be far less satisfactory than the former, in which the leaves and twigs are slashed off after the branches have been cut from the bushes.

Agricultural Factors.

(*a*) The leaving of the prunings on the ground precludes the valuable mechanical effects of soil aeration by the burial of prunings. The blocking of drains is also frequent in a climate of large rainfall. In addition, much valuable moisture is lost to the soil, which can be conserved in burying prunings. It is obvious, then, that, agriculturally, the greatest profit to the soil is not gained by leaving prunings on the ground.

(*b*) In the case of the wholesale burying of prunings, an enormous amount of essential organic matter is returned to the soil, and, in addition, the soil is kept open by the wood

of the buried branches for a considerable time. Were it not for the fact that the borer is able to breed in and emerge from prunings so buried, this method would be ideal from the point of view of cultivation.

(*c*) When prunings are burnt wholesale, the only constituent which it is possible to return to the soil is the ash, comprising, under estate conditions, about 8 per cent. of the total weight of prunings (the actual weight of ash obtained when prunings are burnt in the laboratory is only 2·57 per cent.). This would contain small quantities of nitrogen, the latter disappearing entirely if the burning is thorough ; also potash, about 50 lb. per acre ; phosphoric acid, about 20 lb. per acre. The loss through burning would be about 300 lb. nitrogen and 3,000 lb. moisture per acre, included in a nett bulk of 30,000 lb. of material. Now, it is universally recognized that good cultivation acts as a certain check to the increase of the borer, and this loss of material, though involving a destruction of vast numbers of insects in the prunings, is, to a great extent, counterbalanced by rendering tea bushes generally more open to attack, and also by loss of crop directly due to insufficient cultivation. The burning of prunings wholesale can therefore not be recommended from any point of view, when a profitable method of compromise is open to practice.

(*d*) The burning of the leaves and a great portion of the smaller wood of prunings is a direct and downright waste, as there is no borer contained in them for destruction. It is quite economic to save the small leaves and wood in estate practice by cutting them off, and also to burn the larger wood and return the ash from the latter to the soil. By slashing off the leaves just before pruning the majority of small wood is lost in the fire, and pruning is rendered difficult to the coolies. The only other method of saving the leaves and small wood is the cutting of them from the prunings immediately after pruning, which can be done with ease and despatch. It was pointed out that 4 per cent. of the galleries escaped by the process, but of this 4 per cent., it is certain that not one quarter of the contained broods will reach the surface.

The following are the weights of prunings, showing the proportion of leaf and small wood to large wood :—

Peradeniya, July, 1917. Large tea. Light pruning.

		Per Acre of 2,722 Bushes.
	lb.	lb.
Weight of large wood from 10 bushes .	16	= 4,350
Weight of leaves and small wood ..	27	= 7,350
Total ..	43	= 11,700 per acre.

Lunugala (Uva), April, 1917. Poor tea. Heavy pruning.

		Per Acre of 3,200 Bushes. lb.
Weight of large wood from 28 bushes	42	= 4,800
Weight of leaves and small wood	58	= 6,620
Total	100	= 11,420 per acre.

Taking the average of these, the proportion of leaves and small wood to large wood per acre is roughly as 6 to 4.

The gain and loss of manurial constituents per acre will be as follows :—

		Gain. lb.	Loss. lb.	Total. lb.
	Moisture	700	500	1,200
	Nitrogen	70	30	100
As l	Potash	50	—	50
	Phosphoric acid	20	—	20

These constituents will be contained in a nett bulk of 11,500 lb., of which 7,000 lb. will be returned to the soil as prunings and ash, and 4,500 lb. will be lost in burning.

These figures are purposely given in round numbers, as any detailed calculations would be most misleading. In comparison with the number of insects killed, and with the conservance of a great portion of mechanical soil aeration, the loss through burning the large wood is considered unquestionably very small, and the method of treating the prunings must stand, entomologically and agriculturally, as sound and profitable.

Economic Factors.

It now only remains to consider the various costs of the different methods.

1. Leaving the prunings on the ground exercises practically no control over the pest, and therefore cannot be recommended.

2. The cost of burying the prunings wholesale may be reckoned, giving fair average costs, as follows :—

	Per Acre. Rs.
To cutting 800 holes per acre (40 holes per cooly), 20 coolies, at 40 cents	8
To filling 800 holes per acre (80 holes per cooly), 10 coolies, at 40 cents	4
Total	12

The aeration of soil and return of manurial constituents has been proved to be worth this expenditure, but further than improvement in the resisting powers of tea bushes in general to borer attack no control is exercised upon the insect.

3. Burning prunings wholesale costs about Rs. 4 per acre, involving a dead loss in portions of the prunings which do not contain the beetles, and a general falling off in resistance to attack.

4. The cost of slashing off the leaves and small wood after pruning, and burning the large wood is, roughly, as follows :—

	Coolies.	Per Acre. Rs. c.
To cutting 800 holes per acre (50 holes per cooly at 40 cents) ..	16 ..	6 40
To slashing off small wood and leaves ..	5 ..	2 0
To burying and filling ..	8 ..	3 20
To burning wood and distributing ash ..	6 ..	2 40
Total ..	..	14 0

In this method the cooly can cut more holes, as the latter do not have to be so large as in the burying of prunings wholesale. The same applies to filling, and a saving is afforded over burning wholesale by the smaller bulk of material that has to be carried to the road. The burning of the large wood should be reckoned entirely as a control method against Shot-hole Borer, and should be deducted as chargeable against pests and diseases in estate accounts, thus making the cost of this practice about Rs. 12 to Rs. 12·50 per acre, or about equal to the cost of burying wholesale.

The amount of borer destroyed, and the return of valuable material in bulk to the soil, well warrants the expenditure involved. It might be suggested that the holes for the prunings be cut after pruning, and not before, as generally practised, as great saving in labour is effected by cutting the holes of such a size as to suit the bulk of leaves and small wood to be placed in each hole, a factor which varies much even within limited areas. In heavy tea the holes will be cut nearer together, in light tea further apart.

Conclusions and Summary.

1. From branches left on the ground after pruning, all pupæ, four days previous to reaching maturity, contained in the galleries, will become adult, and will escape as adults, together with all adult beetles already matured in the galleries at the time, in both wet and dry seasons. In wet seasons only late larval stages, all pupæ, and mature beetles will escape as adult beetles similarly.

2. When prunings are buried to depths varying from 4 to 18 inches below the ground, with or without the manurial mixtures commonly used on estates, development in the woody stems proceeds normally below the ground for a period of at least 30 days. From these depths adult female beetles may continue to reach the soil surface during a period of at least 56 days in dry weather, and for a lesser period in heavy rains. Thus, development can take place through a full generation beneath the soil, and adult beetles can find their way through soil of the greatest depth to which it is possible to bury prunings profitably upon estates. Artificial methods of controlling the insect in buried prunings by fumigation, by spraying with, or by dipping in insecticidal solutions, are not practicable owing to the great expense involved in labour, the large quantity of insecticide demanded, the heavy cost of fumigant, and the danger of using poisons.

3. Though all insects are destroyed by the wholesale burning of prunings, but slight heat being sufficient to kill the inmates of the galleries, the loss of manurial constituents to the soil in general bulk and in nitrogen is such as to preclude the method of treatment from being adopted, even though the potash and phosphoric acid may be saved in the ash. Soil aeration, obtained by burying, is also prevented if all the wood of prunings is burnt.

4. The soundest method of treating prunings from all points of view is to cut the leaves and smaller wood up to the thickness of an ordinary pencil from the branches immediately after pruning the bushes. The leaves and small wood, in which the maximum amount of borer is not more than 4 per cent. of the total in the prunings, are buried in holes dug after pruning to suit the size of the prunings thus obtained. The remaining wood is carried to the roadside and burnt. The ashes from the latter may be collected in sacks and broadcasted later, or they may be collected into heaps and covered with the branches of trees, and forked in later as an ordinary estate manure. By this method sufficient soil aeration is obtained from the smaller wood buried, the loss in bulk and nitrogen contained in the thicker wood only being comparatively very small. The cost involved per acre is not much greater than that of burying prunings wholesale, and the amount spent upon the burning of the heavier wood, being entirely of the nature of a control measure for Shot-hole Borer, can be made chargeable to " Control of Insect Pests."

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Peradeniya, November 18, 1918.